R 568

Technical Report

MEASUREMENT OF AIRFIELD MARKING PAINT FLEXIBILITY

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MEASUREMENT OF AIRFIELD MARKING PAINT FLEXIBILITY

Technical Report R-568

Y-F020-03-03-003

by

Eddy S. Matsui and Richard W. Drisko, Ph.D

ABSTRACT

A method for determining the elongation of free paint films is discussed. The method is more precise than the ASTM and Federal Test Standard methods which use the mandrel test, and it provides a more clear-cut differentiation between different coating films.

A statistical analysis was performed on 10 experimental airfield marking paints using data from the free film percent-elongation tests and from performance tests of the same coatings exposed in the field. The results indicate that there is a definite correlation between the percent elongation (flexibility) and the field performance of airfield marking paints.

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INTRODUCTION

Many field activities of the Naval Shore Establishment have found that airfield runway markings and the asphaltic substrate deteriorate rapidly. Studies conducted at the U. S. Naval Civil Engineering Laboratory (NCEL)[1-3] have indicated that flexibility is a prerequisite for good field performance of airfield marking paints.

A method for measuring the flexibility of airfield runway marking paints is given in Federal Specification TT-P-85b. This specification requires that the paint on a te.. panel neither crack nor flake after bending 180 degrees around a 1/2-inch-diameter cylindrical mandrel; evidence of cracking or flaking from the thin metal panel constitutes failure. Thus, test results are reported as either "conformed" or "failed." The results of such flexibility tests of ten experimental airfield runway marking paints from previous studies[1-3] are shown on line 1 of Table 1. It shows that paints 7 and 8 met the qualitative requirement, whereas paints 1, 2, 3, 4, 5, 6, 9, and 10 did not.

It is much more desirable in coating research to have objective and quantitative data rather than just a "conformed" or "failed" notation. Test methods for obtaining quantitative data are described in ASTM Standard D522-60 and in Federal Test Method Standard (FTMS) No. 141, Method 6222. Both use a conical rather than a cylindrical mandrel in the bend test, so that the diameter of the mandrel at which no cracking occurs can be measured. The flexibility of paint films determined by these procedures is expressed in terms of percent elongation of the film. Either test method is satisfactory for routine quality testing, but each has limitations for use in coating research. The measurable range of paint-film elongation using these methods is only from approximately 2 to 8%, depending upon the thickness of the paint film on the panel used as a substrate.

Examples of test results obtained by FTMS No. 141, Method 6222, are given on line 2 of Table 1. It can be seen that only paints 6, 7, 8, and 9 had values in the measurable range of this method, whereas paints 1, 2, 3, 4, 5, and 10 had values less than the lower limit, and their actual percent elongation could not be determined. The measurements were made in triplicate, and the precision of the results is illustrated in Table 2. Line 3 of Table 1 shows data obtained using a free-film method of determining paint flexibility. This method is believed to be more precise and will be described later.

Table 1. Paint-Film Flexibility (Percent Elongation) Determined by Various Test Methods

Test Method	Average Film Thickness (mil)	Paint Sample No.									
		1	2	3	4	5	6	7	8	9	10
TT-P-85b	4.2	F	F	F	F	F	F	C	C	F	F
FTMS No. 141 (%)	6.5	<2.48	<2.44	<2.37	<2.52	<2.24	5.87 1/	7.52 1/	6.70 1/	6.76 1/	<2.33
Gardner Apparatus (%)	7.6	1.28	0.62	0.62	1.60	0.96	5.16	3.96	5.04	5.08	1.00

NOTE. F means failed to meet qualitative requirement.
C means conformed to qualitative requirement.
< indicates less than minimum measurable percent elongation shown.

1/ No cracking or flaking at 1/2-inch mandrel.

Table 2. Analysis of Flexibility (Percent Elongation) Data Obtain by FTMS No. 141, Method 6222

Sample 1/ No.	Average Elongation (%)	Limit at 95% Confidence Interval	Estimated Standard Deviation	Coefficient 4/ of Variation (%)
1	<2.48 2/	• 3/	•	•
2	<2.44	•	•	•
3	<2.37	•	•	•
4	<2.53	•	•	•
5	<2.24	•	•	•
6	5.87	± 0.430	0.173	2.93
7	7.52	± 0.103	0.416	5.53
8	6.70	± 0.74	0.300	4.48
9	6.76	± 0.103	0.416	6.15
10	<2.33	•	•	•

1/ Average film thickness = 6.5 mil.

2/ < indicates less than minimum measurable value shown.

3/ • indicates a value could not be determined.

4/ A measure of relative dispersion about the sample mean.

Past experience indicates that there are a number of paints whose elongation is greater than 8%, as well as a number of paints whose elongation is less than 2%. Also, there are a number of paints which fail to perform satisfactorily in field exposure tests while meeting the flexibility requirement. In order to determine quantitatively the correlation between the flexibility of a coating and its service performance, it is most desirable that the elongation of a paint film be measured more precisely and in a wider range than is available by the above standard methods. This report describes another method that gives quantitative data over a wider range than FTMS No. 141, Method 6222.

FREE-FILM METHOD

Apparatus

The apparatus shown in Figure 1 (Gardner Tensile Strength and Elongation Apparatus) was obtained from Gardner Laboratory Inc., Bethesda, Maryland. It is used to determine the tensile strength, elongation, and elasticity of free films of coating materials. The test paint film, cut to a particular size (as explained later), is fastened to clamps which are adjusted to be 10 cm apart. The upper clamp is moved upward at a rate of either 10 or 30 mm/min, stretching the film and the spring to which the lower clamp is fastened. The elongation of a film, up to 100%, and its load at the time of failure is indicated on the attached scale. The apparatus has two calibrated springs, one for measuring loads up to 500 grams and the other for measuring loads up to 2,500 grams. The calibrated springs provide added data for determining the tensile strength of sample films being measured for elongation. The conical mandrel method of measuring the elongation of sample film does not provide tensile-strength data.

Reference to the Gardner apparatus described and its use in this work does not constitute an endorsement of it in preference to other equipment on the market capable of performing in a similar manner. This paper is directed toward a comparison of test techniques, and no effort has been made to test other products that might be equally effective in determining the elongation of free paint films.

Preparation of Samples

Test films were prepared by the method described by Harris.[4] Each paint was thoroughly mixed, avoiding entrapment of air bubbles which can produce pin holes in the cured films. The film was then cast on a photographic

sheet, double-weight matte, by a motor-driven applicator* equipped with a vacuum plate to hold the substrate flat and a blade of adjustable clearance. After paint was applied, the photographic sheet was removed from the applicator, fastened to a flat glass plate to prevent curling, and air-dried for 2 weeks in a well-ventilated room where the temperature was maintained between 70 and 85°F.

The dried film was stripped from the photographic sheet by wetting the back of the sheet with water. Moisture soaked through the sheet, and the dry film was easily peeled from its surface. The free film was cut into strips 20 by 120 mm using a sharp razor blade. It is important that the strips be of uniform width and thickness and free of nicks along edges and other flaws which might affect experimental results. Acceptable strips were stored in a humidity-controlled storage room with the temperature maintained at 70 to 85°F and a relative humidity of 50 ± 2% for another 2 weeks to assure complete curing under specific conditions before the tests were performed.

Testing Procedure

Care was taken to prevent damage to the test strips by the alligator clamps of the test apparatus by inserting rubber sheets between their jaws. The specimens were fastened with the clamps normal to the direction of pull to prevent premature rupture of the specimen and erroneous readings. Most experimental errors in this test are due to slight variation in preparation or mounting of the samples.

Since ambient temperature and humidity probably have marked influence on the measurement of film elongation, the test should be conducted in a controlled environment for best results. The temperature and relative humidity should be recorded at the time of each experiment if a controlled environment is not used.

The 4 weeks total curing time permitted the paints to cure much as they would in the field. The rate of cure can be accelerated by heating, as done in Specification TT-P-85b and Federal Test Method Standard, No. 141, but the mechanism of curing at an elevated temperature is not the same as that in the field. Thus, there may be some sacrifice in accuracy with accelerated curing. If desired, the extent of this sacrifice can be determined by comparing elongation values received for paints cured for 4 weeks with those of the same paints that have been heat-cured.

* Manufactured by Gardner Laboratory, Bethesda, Maryland.

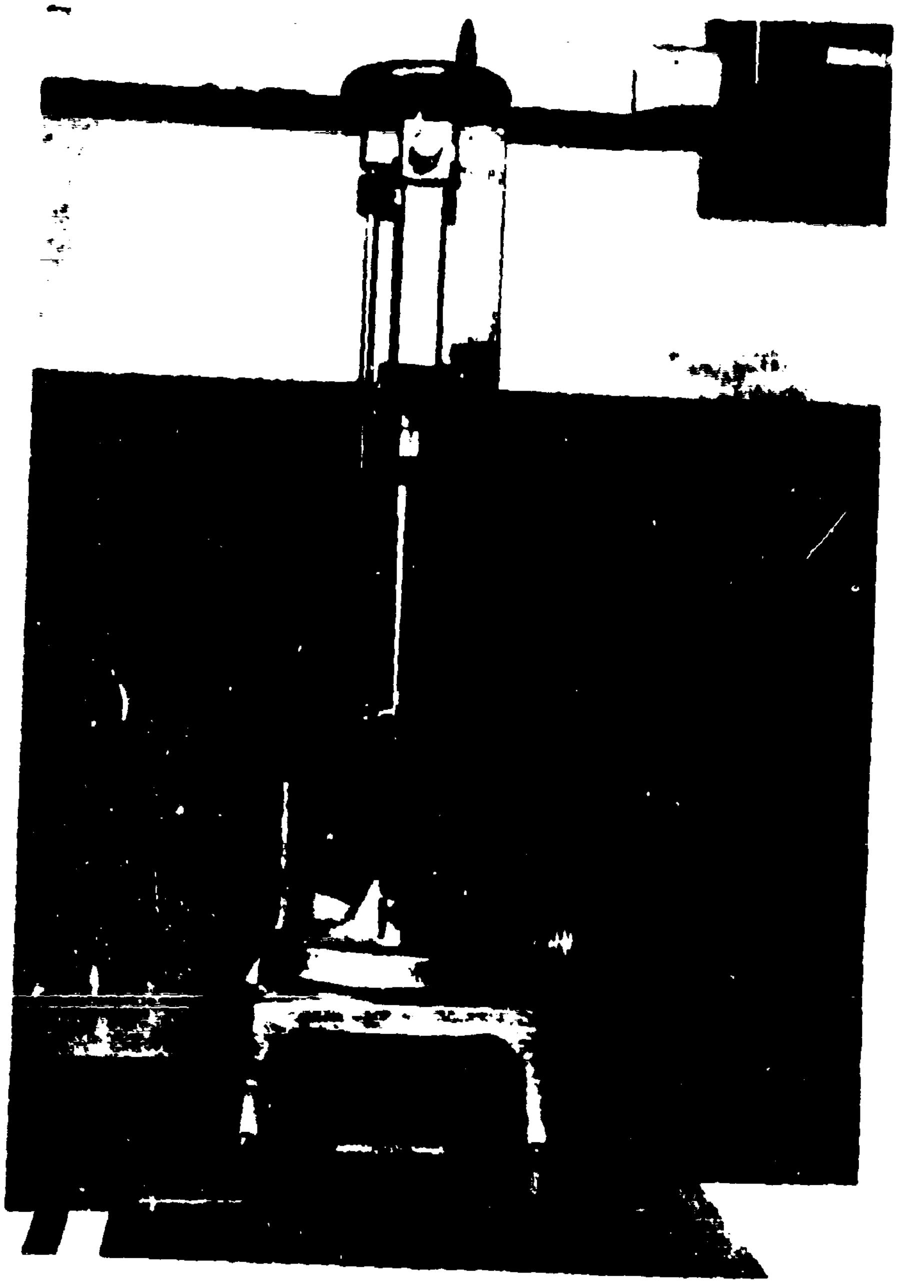

Figure 1. Gardner tensile strength and elongation apparatus.

The specimens described in this report were elongated at the rate of 30 mm/min. The percent elongation and the loading force at the rupture point (R. P.) are read directly from scales on the instrument. Tensile strength is calculated as the pull in grams per square millimeter needed to rupture the specimen. A minimum of five samples were run for each material tested. If one value in a set of five appeared to differ widely from the others, the suspected value was temporarily ignored, and the mean average deviation of the others were computed. If the deviation of the suspected value from the mean of the others was more than four times their average deviation, the suspected value was rejected. If it was not, it was retained, and a new average value and average deviation were computed.

LABORATORY RESULTS

Double-Thickness Films

Results of elongation testing by the above method are given on line 3 of Table 1. Since those elongation measurements were made on free films rather than on films bonded to a substrate as in the two standard methods, the results can be compared only grossly with those from the other methods. The results, however, clearly indicate that the free-film method has extended the measurable range of elongation beyond that of the conical-mandrel method. Table 3 indicates that the precision of the free-film test method was higher overall than that of the conical-mandrel standard method (see Table 2) in the range where flexibility (percent elongation) of the specimens could be assigned quantitative values. The greater precision of the free-film method was determined statistically by the F-test. F, the ratio of variances for elongation values for samples 6, 7, 8, and 9 determined by the two test methods, was 18.8. The critical value of F at the 99.9% confidence level, 3.43, was greatly exceeded, indicating a very highly significant increase in precision by the free-film method. The precision of this method is greatest with specimens having the greatest elongations. This is due to the fact that errors arising from sample preparation and measurement occur more frequently on specimens of low elongation.

The data analysis of tensile strength obtained with the Gardner apparatus is given in Table 4. The coefficients of variation of the data indicate that the overall precision of the tensile-strength determination may be slightly better than that for percent elongation.

Table 3. Analysis of Flexibility (Percent Elongation) Data Obtained by Tensile Strength, Elongation Apparatus

Sample[1] No.	Average Elongation (%)	Limit at 95% Confidence Interval	Estimated Standard Deviation	Coefficient of Variation (%)
1	1.28	±0.103	0.083	6.53
2	0.62	±0.161	0.130	21.03
3	0.62	±0.135	0.109	17.66
4	1.60	±0.124	0.100	6.25
5	0.98	±0.135	0.109	11.17
6	5.16	±0.110	0.089	1.73
7	3.98	±0.103	0.083	2.10
8	5.04	±0.110	0.089	1.77
9	5.06	±0.067	0.054	1.08
10	1.00	±0.361	0.291	29.15

1/ Average film thickness = 7.6 mil.

Table 4. Analysis of Tensile-Strength Data Obtained by Tensile Strength, Elongation Apparatus

Sample[1] No.	Tensile Strength at R. P. (gm/mm^2)	Limit at 95% Confidence Interval	Estimated Standard Deviation	Coefficient of Variation (%)
1	535.8	±29.3	23.6	4.41
2	632.9	±21.8	17.6	2.79
3	518.6	±92.0	74.0	14.27
4	481.6	±57.6	46.4	9.64
5	582.4	±27.2	21.9	3.76
6	522.0	±16.0	12.9	2.47
7	510.0	±34.4	27.7	5.43
8	576.3	±11.0	8.9	1.55
9	482.0	±35.6	28.7	5.96
10	644.8	±17.0	13.7	2.13

1/ Average film thickness = 7.6 mil.

Single-Thickness Films

In addition to the above experiments, paint films of the same ten paints were prepared at one half the previously used thickness, aged for 4 weeks, and tested with the Gardner apparatus. Similar pairs of paints of approximately the same thicknesses were tested by FTMS, No. 141, Method 6222. The tensile-strength and elongation data for both thicknesses are presented in Table 5. They reveal the following general characteristics for the films tested.

Summary of Laboratory Experiments

1. While the load required for film rupture increased with increasing thickness, the tensile strength of the film decreased.

2. Percent elongation to the point of rupture increased as the film thickness increased. It could be expected to decrease with prolonged curing.

3. As a result of relations 1 and 2, percent elongation increased as tensile strength decreased.

4. There is considerably greater relative variation in percent elongation than in tensile strength at a particular film thickness.

APPLICATION OF FREE-FILM METHOD TO PREVIOUS STUDIES

Determining flexibility and tensile strength of paint films may be useful in predicting the durability of these paints. Schurr[5] and others have indicated that tensile strength versus time curves correlated well with durability of exterior house paints. Tests conducted at NCEL[1-3] have indicated that good paint flexibility is necessary for optimum performance of airfield marking paints.

An initial effort[1] at NCEL to establish a quantitative correlation between the flexibility and performance of airfield marking paints was unsuccessful because elongation values could not be determined quantitatively by the FTMS Method for paints of low flexibility (see Table 1). The free-film method of determining percent elongation does provide the quantitative data necessary for determining such a correlation.

Table 5. Elongation and Tensile-Strength Data of Ten Paints Obtained by Two Test Methods

(Tensile-strength data unobtainable with standard method)

Paint No.	Gardner Tensile Strength, Elongation Apparatus				FTMS, No. 141, Method 6222	
	Thickness (mil)	Load at R. P.[1] (gm)	Tensile Strength at R. P. (gm/mm^2)	Elongation (%)	Thickness (mil)	Elongation (%)
1	7.4 3.5	2,002 1,510	535.8 861.0	1.28 0.48	7.0 4.5	<2.46 <1.95
2	7.8 3.8	>2,500 1,598	>632.9 832.5	0.62 0.42	6.9 4.4	<2.44 <1.92
3	8.1 3.7	2 274 1,406	518.6 756.3	0.62 0.36	6.6 4.2	<2.37 <1.87
4	8.1 3.5	2,064 1,710	481.6 962.1	1.60 0.44	7.3 4.1	<2.52 <1.86
5	7.1 3.5	2,094 1,150	582.4 647.4	0.98 0.20	5.9 3.9	<2.24 <1.83
6	7.8 3.6	2,050 1,252	522.0 683.3	5.16 2.32	5.9 4.2	5.87 2.73
7	7.3 3.3	1,846 1,226	510.0 722.8	3.98 2.92	6.7 4.4	7.52 3.55
8	7.1 3.0	2,090 1,047	576.4 673.8	5.04 2.48	6.1 3.9	6.70 3.65
9	7.8 3.1	1,908 1,150	482.1 727.0	5.06 2.52	6.5 4.7	6.76 2.11
10[2]	7.5 3.3	2,480 1,084	644.8 646.2	1.00 1.46	6.4 3.9	<2.33 <1.83

1/ R. P. = Rupture point.

2/ Too brittle to measure accurately.

Correlation Between Percent Elongation (Flexibility) and Edge-Cracking of Paint Stripes

Sample films of twenty airfield marking paints used in previous NCEL field tests[1-3] were prepared, and their elongations were measured as described in the preceding section of this report. Elongation values of the twenty paints

at the two different film thicknesses are shown in Table 6, together with the corresponding ratings of edge cracking of slurry seal along painted stripes obtained from NCEL Technical Report R-400.[1] Reference 1 describes in detail the experimental marking paint formulations and their application as test stripes to plots of slurry-sealed and unslurried asphaltic pavement in a randomized and replicated statistical pattern. The edge-cracking ratings recorded in December 1964, 7 weeks after paint application, were used to determine the correlation with percent elongation because at that time they showed a maximum variation, making conclusions drawn from these data most meaningful.

The correlations between the edge-cracking of single-thickness stripes and the percent elongation of the two different thicknesses were found to have a high statistical significance. Coefficients of correlation (r) were 0.57 for the thicker film and 0.52 for the thinner film. Critical correlation values of different levels of significance are indicated in Table 7.

Edge-cracking ratings of double-thickness stripes at the time of maximum variation, however, failed to show a significant correlation with paint flexibility (Table 7). This was probably due in large part to the greater amount of edge-cracking in double-thickness stripes compared with single-thickness stripes at this time.

Correlation Between Percent Elongation (Flexibility) and Lifting of Stripes

The elongation values in Table 6 of the twenty paints with two different thicknesses are listed in Table 8 along with the ratings of slurry-seal lifting under test stripes obtained from NCEL Technical Report R-499.[2] Lifting ratings of April 1965, 6 months after paint application, were selected for determining correlation, because they had the greatest variation at this time.

Statistical analysis indicated that the correlations between the flexibility at the two different free-film thicknesses and the lifting ratings of two different thicknesses of stripe were found to range from statistically significant to very highly significant, the significance being much greater for double- than for single-thickness stripes. The coefficients of correlation between flexibility and lifting of painted stripes in the field are given in Table 7, together with the critical value at different levels of significance. Correlation between flexibility and corresponding lifting ratings, disregarding the effect of thickness, was very highly significant ($r = 0.48$, where the critical value of significance at 99.9% level is 0.36).

Table 6. Edge-Cracking Ratings (December 1964) and Flexibility (Elongation) of Twenty Paints[1]

Percent (10 indicates no cracking; 0 indicates complete cracking)

Paint Formulation		Test Plot 1				Test Plot 2				Subtotal		Elongation (%)	
		W_1 1/		W_2 2/		W_1		W_2					
		S 3/	D 4/	S	D	S	D	S	D	S	D	S	D
1	C_1 5/	8	6	8	7	3	2	4	2	23	17	0.20	0.28
	C_2 6/	9	9	9	9	7	8	7	9	32	35	0.48	1.28
2	C_1	10	10	10	10	6	9	8	10	34	39	0.46	0.50
	C_2	10	9	9	9	7	8	7	8	33	34	0.42	0.62
3	C_1	6	9	6	9	1	8	1	8	14	34	0.30	0.48
	C_2	4	2	5	5	8	8	8	7	25	22	0.36	0.62
4	C_1	10	10	10	10	8	9	8	10	36	39	0.68	0.40
	C_2	10	10	9	10	8	10	8	10	35	40	0.44	1.60
5	C_1	1	1	1	0	0	0	1	1	3	2	0.20	0.26
	C_2	3	0	3	0	6	0	7	0	19	0	0.20	0.98
6	C_1	10	10	10	10	10	10	10	10	40	40	2.74	4.54
	C_2	10	10	10	10	10	10	10	10	40	40	2.32	5.16
7	C_1	10	10	10	10	8	10	8	10	36	40	1.62	4.66
	C_2	10	9	9	8	10	9	9	9	38	35	2.92	3.98
8	C_1	9	9	9	10	7	7	7	6	32	32	2.96	4.12
	C_2	9	9	9	8	9	7	8	9	35	31	2.48	5.04
9	C_1	10	10	10	10	9	10	4	10	33	40	2.24	4.28
	C_2	8	7	7	10	5	7	7	6	27	30	2.52	5.06
10	C_1	6	0	4	0	8	0	8	0	26	0	1.48	2.10
	C_2	7	0	6	0	0	1	4	0	17	1	1.46	1.00

1/ W_1 = 4-Inch Width

2/ W_2 = 12-Inch Width

3/ S = Single Thickness

4/ D = Double Thickness

5/ C_1 = With Carbon Black

6/ C_2 = Without Carbon Black

Table 7. Coefficient of Correlation Between Free-Film Elongation and Edge-Cracking, Paint Lifting, Paint Deterioration

(Critical value of significance at 95% level = 0.44, significant)
(Critical value of significance at 99% level = 0.56, highly significant)
(Critical value of significance at 99.9% level = 0.68, very highly significant)

Free-Film	Edge-Cracking		Paint Lifting		Paint Deterioration	
	S[1]	D[2]	S	D	S	D
Lesser thickness	0.52	0.42	0.58	0.65	0.85	0.64
Greater thickness	0.57	0.31	0.46	0.73	0.75	0.72

1/ S = Single-thickness stripes.
2/ D = Double-thickness stripes.

Correlation Between Percent Elongation (Flexibility) and Deterioration of Paint Stripes on Unslurried Asphalt

The same flexibility values of twenty paints with two different thicknesses (Tables 6 and 8) are listed in Table 9 along with the ratings of paint deterioration on unslurried asphalt obtained from NCEL Technical Report R-500.[3] The deterioration ratings recorded on February 1966, 15 months after paint application, were selected for analysis under the same reasoning as stated in the two preceding sections.

Statistical analysis indicated that the correlations between the flexibility at two different free-film thicknesses and the deterioration at two different stripe thicknesses ranged from highly significant to very highly significant. The coefficients of correlation between flexibility and deterioration of paint on unslurried asphalt are given in Table 7, together with the critical values at different levels of significance. Correlation between flexibility and corresponding paint deterioration rate, disregarding the effect of thickness, was very highly significant ($r = 0.63$, whereas the critical value of significance at the 99.9% level is 0.36).

CONCLUSIONS

The free-film method of determining paint elongation is more precise than the methods using a mandrel and has a wider range of values. Tensile strength of paint films can also be determined by this method.

Table 8. Lifting Ratings (April 1965) and Flexibility (Percent Elongation) of Twenty Paints[2]

(Rating of 4 is high, rating of 1 is low)

Paint Formulation		Test Plot 1				Test Plot 2				Subtotal		Elongation (%)	
		W_1 1/		W_2 2/		W_1		W_2					
		S 3/	D 4/	S	D	S	D	S	D	S	D	S	D
1	C_1 5/	4	3	3	2	4	2	3	3	14	10	0.20	0.28
	C_2 6/	2	2	2	2	4	2	2	2	10	8	0.48	1.28
2	C_1	4	3	3	3	4	3	4	3	15	12	0.46	0.50
	C_2	3	2	2	3	4	3	3	3	12	11	0.42	0.62
3	C_1	2	2	3	2	3	1	3	1	11	6	0.30	0.48
	C_2	2	2	2	2	3	2	2	2	9	8	0.36	0.62
4	C_1	2	2	3	2	4	3	4	3	13	10	0.68	0.40
	C_2	3	2	2	3	3	3	3	3	11	11	0.44	1.60
5	C_1	4	1	4	1	4	1	3	1	15	4	0.20	0.26
	C_2	4	1	3	1	4	1	2	1	13	4	0.20	0.98
6	C_1	4	1	4	3	4	4	4	4	16	15	2.74	4.54
	C_2	4	4	4	4	4	4	3	4	15	16	2.32	5.16
7	C_1	4	4	4	3	4	4	4	4	16	15	1.62	4.66
	C_2	4	4	4	4	4	4	4	4	16	16	2.92	3.98
8	C_1	4	3	3	3	4	4	4	3	15	13	2.96	4.12
	C_2	4	4	3	3	4	4	4	3	15	14	2.48	5.04
9	C_1	4	3	3	4	4	3	3	3	14	13	2.24	4.28
	C_2	2	3	3	2	4	4	4	3	13	12	2.52	5.06
10	C_1	4	1	4	1	4	1	4	1	16	4	1.48	2.10
	C_2	4	1	4	1	4	1	4	1	16	4	1.46	1.00

1/ W_1 = 4-Inch Width
2/ W_2 = 12-Inch Width
3/ S = Single Thickness
4/ D = Double Thickness
5/ C_1 = With Carbon Black
6/ C_2 = Without Carbon Black

Table 9. Paint Deterioration Ratings (February 1966) and Flexibility (Percent Elongation) of Twenty Paints[3]

(Rating of 3 is high, rating of 1 is low)

Paint Formulation		Test Plot 1				Test Plot 2				Subtotal		Elongation (%)	
		W_1 1/		W_2 2/		W_1		W_2					
		S 3/	D 4/	S	D	S	D	S	D	S	D	S	D
1	C_1 5/	2	2	2	2	2	2	2	2	8	8	0.20	0.26
	C_2 6/	2	2	2	2	2	2	1	2	7	8	0.48	1.26
2	C_1	2	2	2	2	2	2	3	2	9	8	0.46	0.50
	C_2	3	2	2	2	2	2	2	3	9	9	0.42	0.62
3	C_1	2	2	2	2	2	1	2	1	8	6	0.30	0.46
	C_2	2	2	2	2	2	2	2	2	8	8	0.36	0.62
4	C_1	2	2	2	2	3	2	2	2	10	8	0.68	0.40
	C_2	2	2	2	2	2	2	2	2	8	8	0.44	1.60
5	C_1	2	2	2	1	2	1	1	1	7	5	0.20	0.26
	C_2	2	1	2	1	2	1	2	1	8	4	0.20	0.98
6	C_1	3	3	3	3	3	3	3	3	12	12	2.74	4.64
	C_2	3	3	3	3	3	3	3	3	12	12	2.32	5.16
7	C_1	3	3	3	3	3	3	3	3	12	12	1.62	4.66
	C_2	3	2	3	3	3	3	3	3	12	11	2.92	3.98
8	C_1	3	3	3	2	3	3	3	2	12	10	2.96	4.12
	C_2	3	2	3	2	3	2	3	2	12	8	2.48	5.04
9	C_1	3	3	2	3	2	3	2	2	9	11	2.24	4.26
	C_2	3	2	2	3	3	2	3	2	11	9	2.52	5.06
10	C_1	2	2	2	2	3	2	2	2	9	8	1.48	2.10
	C_2	3	1	3	1	3	1	3	1	12	4	1.46	1.00

1/ W_1 = 4-Inch Width 3/ S = Single Thickness 5/ C_1 = With Carbon Black

2/ W_2 = 12-Inch Width 4/ D = Double Thickness 6/ C_2 = Without Carbon Black

Overall results of statistical analysis indicate that there is a definite correlation between flexibility (percent elongation) and field performance of airfield marking paints. Although it is not expected that any one factor, such as flexibility, is so important that it alone can be used as a basis for predicting performance of paints, paints with poor flexibility can not be expected to perform as well as similarly formulated paints with greater flexibility.

RECOMMENDATION

Other available equipment for measuring flexibility appears to be worth investigating. It is possible that there may be a device which can measure the elongation more precisely and accurately than the devices presently used.

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MEASUREMENT OF AIRFIELD MARKING PAINT FLEXIBILITY

Not Final; September 1966 to July 1967

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March 1968	16	5

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TR-568

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Naval Facilities Engineering Command
Washington, D. C.

A method for determining the elongation of free paint films is discussed. The method is more preciso than the ASTM and Federal Test Standard methods which use the mandrel test, and it provides a more clear-cut differentiation between different coating films.

A statistical analysis was performed on 10 experimental airfield marking paints using data from the free-film percent-elongation tests and from performance tests of the same coatings exposed in the field. The results indicate that there is a definite correlation between the percent elongation (flexibility) and the field performance of airfield marking paints.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Free-film tests						
Mandrel tests						
Correlation with deterioration						
Edge-cracking						
Lifting						
Tensile strength						

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Subj: Errata Sheet for Technical Report TR-568, "Measurement of Airfield Marking Paint Flexibility," by Eddy S. Matsui and Richard W. Drisko, Ph D, March 1968

Encl: (1) Replacement page for subject report

1. Remove pages 1 and 2 from subject report and replace them with enclosure (1).

Table 1. Paint-Film Flexibility (Percent Elongation) Determined by Various Test Methods

Test Method	Average Film Thickness (mil)	Paint Sample No.									
		1	2	3	4	5	6	7	8	9	10
TT-P-85b	4.2	F	F	F	F	F	F	C	C	F	F
FTMS No. 141 (%)	6.5	<2.46	<2.44	<2.37	<2.52	<2.24	5.87 1/	7.52 1/	6.70 1/	6.76 1/	<2.33
Gardner Apparatus (%)	7.6	1.28	0.62	0.62	1.60	0.98	5.16	3.98	5.04	5.06	1.00

NOTE. F means failed to meet qualitative requirement.
C means conformed to qualitative requirement.
< indicates less than minimum measurable percent elongation shown.

1/ No cracking or flaking at 1/2-inch mandrel.

Table 2. Analysis of Flexibility (Percent Elongation) Data Obtained by FTMS No. 141, Method 6222

Sample 1/ No.	Average Elongation (%)	Limit at 95% Confidence Interval	Estimated Standard Deviation	Coefficient 4/ of Variation (%)
1	<2.46 2/	• 3/	•	•
2	<2.44	•	•	•
3	<2.37	•	•	•
4	<2.53	•	•	•
5	<2.24	•	•	•
6	5.87	± 0.430	0.173	2.93
7	7.52	± 0.103	0.416	5.53
8	6.70	± 0.745	0.300	4.48
9	6.76	± 0.103	0.416	6.15
10	<2.33	•	•	•

1/ Average film thickness = 6.5 mil.

2/ < indicates less than minimum measurable value shown.

3/ • indicates a value could not be determined.

4/ A measure of relative dispersion about the sample mean.

INTRODUCTION

Many field activities of the Naval Shore Establishment have found that airfield runway markings and the asphaltic substrate deteriorate rapidly. Studies conducted at the U. S. Naval Civil Engineering Laboratory (NCEL)[1-3] have indicated that flexibility is a prerequisite for good field performance of airfield marking paints.

A method for measuring the flexibility of airfield runway marking paints is given in Federal Specification TT-P-85b. This specification requires that the paint on a test panel neither crack nor flake after bending 180 degrees around a 1/2-inch-diameter cylindrical mandrel; evidence of cracking or flaking from the thin metal panel constitutes failure. Thus, test results are reported as either "conformed" or "failed." The results of such flexibility tests of ten experimental airfield runway marking paints from previous studies[1-3] are shown on line 1 of Table 1. It shows that paints 7 and 8 met the qualitative requirement, whereas paints 1, 2, 3, 4, 5, 6, 9, and 10 did not.

It is much more desirable in coating research to have objective and quantitative data rather than just a "conformed" or "failed" notation. Test methods for obtaining quantitative data are described in ASTM Standard D522-60 and in Federal Test Method Standard (FTMS) No. 141, Method 6222. Both use a conical rather than a cylindrical mandrel in the bend test, so that the diameter of the mandrel at which no cracking occurs can be measured. The flexibility of paint films determined by these procedures is expressed in terms of percent elongation of the film. Either test method is satisfactory for routine quality testing, but each has limitations for use in coating research. The measurable range of paint-film elongation using these methods is only from approximately 2 to 8%, depending upon the thickness of the paint film on the panel used as a substrate.

Examples of test results obtained by FTMS No. 141, Method 6222, are given on line 2 of Table 1. It can be seen that only paints 6, 7, 8, and 9 had values in the measurable range of this method, whereas paints 1, 2, 3, 4, 5, and 10 had values less than the lower limit, and their actual percent elongation could not be determined. The measurements were made in triplicate, and the precision of the results is illustrated in Table 2. Line 3 of Table 1 shows data obtained using a free-film method of determining paint flexibility. This method is believed to be more precise and will be described later